TITLE OF THE INVENTION

A Method For Controlling Operation Of A Mobile Device By Detecting Usage Situations.

TECHNICAL FIELD OF THE INVENTION

The present invention relates generally to a method for controlling operation of a mobile device based on its usage situation, and relates more specifically to a method for correlating sensor data, user operations and usage situations.

BACKGROUND OF THE INVENTION

Most mobile devices, such as mobile telephones, have a multitude of different options and functionalities available for the user of said device. For example, a user of the mobile device can typically select stored telephone numbers for dialing, change the ringing volume of the device, change the luminosity of a display of the device, and the like. Such options and functionalities are typically presented and manually selectable through a programmed user interface utilized by the device.

Prior solutions for controlling the operations of a mobile device include manual control by the user according to the usage situation or the straight forward use of a single sensor condition, such as automatic display lighting if the level of ambient light is low or automatic audio volume setting according to the surrounding noise level monitored by a microphone.

However, it would be advantageous if such a device could more readily and automatically adapt to external conditions based on a multitude of sensor data. Thus, there is a need for efficient gathering and use of context-awareness data in mobile communications, where communication situations may vary significantly.

BRIEF SUMMARY OF THE INVENTION

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According to one embodiment of the present invention, a method for controlling the user interface of a mobile communication device, such as a mobile telephone, having at least one sensor includes: (1) storing analog or digital sensor signals indicative of a plurality of external conditions over a

5 period of time, (2) segmenting said sensor signals into a sequence of sensor data segments, such as by time series segmentation, (3) storing an indication of an operation performed by the user during at least one of said sensor data segments, and (4) determining a rule for future operation of the device, the rule corresponding to said sensor data segments and the

10 operation. The rule may be stored in a rule database in a memory of the device. The segmenting of sensor signals may be perfomed substantially in real time with said storing the sensor signals. The segmenting may be performed after a predetermined amount of sensor signals are stored.

15 According to a further embodiment of the present invention, a method for controlling the user interface of a mobile communication device includes the further steps of detecting a plurality of external conditions, searching a rule database to find a rule matching the external conditions,

20 and performing a function corresponding to the rule.

According to various embodiments of the present invention, the rule may correspond to a change in a user interface.

25 According to still further embodiments of the present invention, a rule for operation may be downloaded from an external source, such as by wireless communication from a computer server.

According to still further embodiments of the present invention, the

30 external conditions monitored by the sensors may include a detected acceleration, a noise level, a luminosity and a humidity.

BRIEF DESCRIPTION OF THE DRAWINGS

35 In the following, the invention will be described in more detail with reference to the appended figures, showing typical applications of the method described in the present invention.

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FIG. 1 is a depiction of an exemplary device and an exemplary process for determining rules employed by the device, according to certain embodiments of the present invention;

5   FIG. 2 is a chart depicting an exemplary correlation of user interaction with the device of FIG. 1 and data stored by the sensors of such device in a learning phase for determining a rule of use; and

FIG. 3 is a chart depicting an exemplary situation in which the device
10   will recognize a similar sensor pattern as in FIG. 2 and select the rule stored determined during the learning phase.

DETAILED DESCRIPTION OF THE INVENTION

15   A mobile device of the present invention includes one or more sensors that are capable of determining various information about the context of the device and the user's current environment. Said sensor(s) can be, for example, acceleration, noise level, luminosity and humidity sensors. The sensors can be used to monitor the external physical conditions,
20   the user himself or some actions of the user. The present invention provides a method for exploiting the information provided by said sensors. The information can be used 1) for controlling the operations of the mobile device and 2) for indexing and organizing the sensor data for user interfaces, retrieval and analysis. Examples of such include 1)
25   launching applications according to a certain context, e.g., setting the phone to a silent mode in a concert or retrieving time-table infomation for public transportation, and 2) indexing information for recall using context-specific terminology, e.g., "Show incoming calls while walking at a railway station."
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In the present invention, time-series segmentation is used to divide sensor data into non-overlapping, internally homogeneous segments. The segments that are found reflect certain states where the device, and its user, are. Compact representations of the recognized segments
35   are used as templates against which the actions of the user (e.g. phone calls) are compared, so that prediction of future actions becomes possible. Formally, the segmentation problem is a special case of general clustering problem, but the temporal structure of the data

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provides additional restrictions that can be used to speed up the computations.

The method described in the present invention describes an effective and sophisticated way of utilizing data from one or more sensors that detect a plurality of external conditions in order to control the operations of a mobile device, thus rendering it context-aware and greatly enhancing its usability.

The sensor data segmented by the device may be raw sensor data, that is, data received directly from the sensor, or pre-processed sensor data, in which the data is first processed to render it in more useful form. In considering data from a luminosity sensor, for example, the raw sensor data may be pre-processed using a Fourier transform or the like to generate a frequency spectrum, which then may be segmented within the scope of the present invention. In such a case, the pre-processed luminosity sensor data may be used to more accurately determine, based on the frequency spectrum, whether detected ambient light is natural or artificial, corresponding to a user being inside or outdoors. Furthermore, such pre-processed sensor data may be more readily compressed, thereby decreasing the amount of time needed to later process or perform calculations using such data. Any combination of raw and preprocessed sensor data may likewise be used.

Recognizing the context of use in more detail is important in making mobile devices as simple to use as possible. Recognition of the user's situation can be used to provide an adaptive and personalized user interface. The use of sensors in a mobile device to determine the context of the device and user is not solved merely by adding said sensors to said devices. To infer more precise and usable information of said context demands for use of different types of sensors to be used and larger amounts of data to be collected. To be able to use this data efficiently, it has to be processed efficiently to infer usable information and to yield a usable compressed representation of the data.

The present invention describes a method for dividing sensor data into non-overlapping, internally homogenous segments which are found to

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reflect different states of the mobile device. By collecting sensor data in different usage situations, processing the data by dividing it into said segments, and then correlating said segments with corresponding usage situations and user operations, it is possible for the device to recognize the relationships between sensor data and context. After this learning phase, the device can infer its context by collecting real-time sensor data, segment the data, and detect its usage situation according to the learned correspondence between the segments and usage situations. Furthermore the device can initiate or predict operations on said device based on the previous or learned correspondences between sensor data segments, usage situations and typical user operations in those usage situations. In this way information about the context of, say, a mobile phone can be used to improve the user interface. For example, if we know from the context that the user is running, the font used in the display can be made larger.

The method described in the present invention is especially well suited for communication mobile devices, such as mobile telephones. Succesful human communication is typically contextual. Communication varies depending on with the user is communicating, where the user is located, what time it is, whether other people are in proximity of the user, what usage situations have occured in the past, and the like. Accordingly, there is a lot of context information that can be used from every-day experiences of the user. The need for context-awareness is especially large in mobile communications, where the communication situations can vary significantly.

In the present invention a method for achieving said context awareness is described based on time series segmentation of sensor data in context recognition for mobile devices. An implementation for the time series segmentation of the sensor data is described that gives approximately optimal results in a fraction of the time required by dynamic programming. This implementation can be used to solve the segmentation problem in time $O(kN)$ with very small constants as contrasted with that of dynamic programming $O(kN^2)$. Where as dynamic programming can be used to find segmentations that minimize the intra-segment variances, the implementation described in the present invention entails, for some instances of the segmentation

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problem, a less-than-optimal solution but is faster and sufficient for the end result for the segmentation problem as described in the present invention.

5   The present invention describes a method for controlling the user interface operation of a mobile device by modifying the device's user interface according to previoulsy detected and analysed usage situations of the user.

Referring to FIG. 1, The mobile device 10 includes communication hardware
10   and software 8 for implementing mobile communications functions, one or more sensors 9 and a memory 7 for storing both processing instructions that enable the functionality described herein and a rules database 6 for storing rules of operation, as described further below.

15   The device 10 may operate generally according to the following method. One or more sensors 9 built into the mobile device 10 are used to collect and store ambient sensor signals as either analog or digital data (step 1). The sensor data is segmented rendering a representation of the signal as a sequence of sensor data segments (step 2). User operations are registered
20   and correlated to the collected sensor data (step 3). Rules of use based on the correlation are determined and stored in a rules database 6 in said mobile device 9 based on the sensor data segments and consistent user operations performed on the mobile device in said segments (step 4). This step can also include the recognition of consistent occurrence of certain
25   subsequences of segments in said sequence of sensor data segments. Finally, the device 10 may continuously search said rules database to find a matching sequence of sensor segments and user operations in order to determine whether the user interface of said mobile device is to be modified in order to reflect settings of said device in that particular situation identified
30   by the rule found reflecting the existence of said previoulsy detected and analysed usage situation (step 5).

The control of the user interface of a mobile device includes controlling the operations of the mobile device by initiating or predicting operations
35   and indexing and organizing the sensor data for user interfaces, retrieval and analysis.

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The step of segmenting sensor data can be implemented so that the collected sensor signals are segmented in real time or segmented after a certain amount of data is collected and stored.

5   The rules in the rules database 6 describe consistent user operations on said mobile device 10 occuring in a certain sensor data segment. Furthermore, the rules describe sequences of sensor data segments that consistently occure dependently of each other and user operations on said mobile device occuring in the segments of said sequence of
10 sensor data segments.

A method for controlling operation of a mobile device 10 described in the present invention may include two phases: 1) a learning phase wherein sensor data is stored, user operations are detected and
15 logged, sensor data is segmented and rules are defined based on a correlation of the user operations and the sensor data, and 2) a usage phase wherein sensor data is monitored to determine conditions relevant to implementing a stored rule, retrieving the rule from the rule database when the condition is detected, and implementing the
20 operation in accordance with the rule. The rule may include, for example, dimming the display in dark luminosity conditions, displaying a larger font when the user is moving, or other similar changes to the user interface.

25 The two phases described above can be sequential so that the operation is first learned before being implemented. Alternatively, a predetermined rule may downloaded into it from an external source. Furthermore these phases can run concurrently or in parallel so that the device 10 is defining or extending and adjusting the rule database 6
30 while the device 10 is being used.

According to certain embodiments of the present invention, the device 10 maps continuous sensor signals (or discrete sampled sensor signals) to sequences of events and achieving a compression of the
35 data. Also, simple and efficient implementations for yielding the necessary segmentations are described in the present invention. The method described in the present invention is not solely restricted to the

presented implementations of the time series segmentation, but can be modified within the scope of the appended claims.

As described in detail below, two efficient implementations of algorithms for the segmentation of time series data are contemplated. For the purpose of being able to describe these algorithmic procedures, notions of time series, segments and cost function are defined.

A time series s consists of N samples $x(1), x(2), ..., x(N)$. The notation $s(a,b)$ defines a segment of the series s, that is, the consecutive samples $x(a), x(a+1), ...; x(b)$ where $a \leq b$. If $s_1 = s(a,b)$ and $s_2 = s(b+1,c)$ are two segments, then $s_1 s_2 = s(a,c)$ denotes their concatenation.

A k-segmentation S of s is a sequence $s_1 s_2 \cdots s_k$ of k segments such that $s_1 s_2 \cdots s_k = s$ and each s_i is non-empty. In other words, there are segment boundaries $c_1, c_2, ..., c_{k-1}, 0 < c_1 < c_2 < \cdots < c_{k-1} < N$, where $s_1 = s(1, c_1), s_2 = s(c_1 + 1, c_2), ...; s_k = s(c_{k-1} + 1, N)$, $c_0 = 0$ and $c_k = N$.

Only internally homogenous segmentations of time series are to be used. To describe this goal formally, a cost function F is associated with the internal heterogeneity of individual segments and is used to minimize the overall cost of the segmentation. Two assumptions are made on the overall cost. First, the cost $\text{cost}_F(s(a,b))$ of a single segment is a function of the data points and the number of data points $n = b - a + 1$. Accordingly:

$$\text{cost}_F(s(a,b)) = F(x; n | x \in s(a,b)).$$

Secondly, the cost of a k-segmentation $\text{Cost}_F(s_1 s_2 \cdots s_k)$ is the sum of the costs of its segments $s_1, s_2, ..., s_k$:

$$\text{Cost}_F(s_1 s_2 \cdots s_k) = \sum_{i=1}^{k} \text{cost}_F(s_k).$$

An optimal k-segmentation $S_F^{opt}(s;k)$ of time series s using cost function cost_F is such that $\text{Cost}_F(s_1 s_2 \cdots s_k)$ is minimal among all possible k-segmentations.

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The cost function F may use the sum of variances of the components of the segment:

$$V(s(a,b)) = \sum_{l=1}^{d} \left[\frac{1}{n} \sum_{i=a}^{b} x_l(i)^2 - \left(\frac{1}{n} \sum_{i=a}^{b} x_l(i) \right)^2 \right],$$

where $n = b - a + 1$ and d is the number dimensions. Thus the cost function for segmentations is

$$Cost_V(s_1 s_2 \cdots s_k) = \frac{1}{n} \sum_{i=1}^{k} n_i V(s_i),$$

where the segments have length $n_1, n_2, \ldots, n_k$, the length N of the sequence is $\sum_{i=1}^{k} n_i$ and $V(s_i)$ is defined as above. Other cost functions are readily contemplated to be used with the present invention.

The problem to be solved is to find the segment boundaries c_i that minimize the cost. For this end two efficient algorithms are described in the present invention.

A local iterative replacement (LIR) algorithm is a simple procedure where a new place for a breaking point constituting for a segment break point is selected optimally between the neighboring two break points (including the beginning and ending of the time series). The break points may be moved gradually towards better positions rather than to the locally optimal ones.

According to this LIR function, initial break points are selected heuristically, e.g. by using evenly spaced or random initial locations, or with a top-down method. A break point $c_i, 1 \leq i \leq k-1$ is then selected either in random or sequential order. The break point is then removed and the two consecutive segments that meet at c_i are concatenated into $s(c_{i-1} + 1, c_{i+1})$. Next, a new optimal location for the break point in the concatenated sequence is determined by locating an optimal 2-segmentation break point c_i' for the concatenated segment and replacing the break point c_i by c_i' in the solution. Selection of the break

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point and determination of a new optimal location are then repeated until a predetermined stopping criterion is met (i.e. a cost is determined that is less than a predetermined threshold value).

In a global iterative replacement (GIR) algorithm, instead of relocating the break point c_i between its neighbours c_{i-1} and c_{i+1}, the best location is searched in the whole sequence. This includes clearly local iterative replacement but it may avoid some local minima. GIR makes one-at-a-time, optimal, split segment-merge segment pairs, and keeps the number of segments constant.

According to the GIR process, the initial segmentation $S_n = s_1 s_2 \cdots s_k; n = 0$ is set, as in LIR. A break point $c_i, 1 \le i \le k-1$ is selected either in random or sequential order, and then removed. The two consecutive segments that meet at c_i are then concatenated into $\hat{s} = s(c_{i-1}+1, c_{i+1})$. Next, a new optimal location for a break point anywhere in the sequence is found by finding for each segment $s_j', j = 1, 2, \ldots, k-1$ in the new segmentation $S' = s_1 s_2 \cdots s_{i-1} \hat{s} s_{i+2} \cdots s_k \equiv s_1' s_2' \cdots s_{k-1}'$ the optimal 2-segmentation to s_{j1}' and s_{j2}', and computing the respective, potential savings $d_j = \cos t_F(s_j') - (\cos t_F(s_{j1}') + \cos t_F(s_{j2}'))$ in the segmentation cost. The split s_l' with the largest savings d_l is then selected and the break point is set at d_l, the new segmentation becoming $s_1' s_2' \cdots s_{l1}' s_{l2}' \cdots s_{k-1}'$. For $n = n+1$, the segments are renumerated for next round as $S_n = s_1 s_2 \cdots s_k \equiv s_1' s_2' \cdots s_{l1}' s_{l2}' \cdots s_{k-1}'$. These steps are then repeated until stopping criterion is met, as in the LIR process.

A natural stopping criterion for the two above algorithms, LIR and GIR, is that the total cost cannot be decreased by any admissible move of a break point leading to a finite number of algorithm steps. Also the number of iterations can be limited in advance.

As an example of the use of the method described in the present invention and an application of the algorithms described above, FIG. 2 shows segmented sensor data collected from sensors 9 in different usage situations, showing clearly the transitions between non-overlapping and internally homogenous segments.

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Turning now to FIG. 2, therein is displayed a chart displaying sensor data and user situations at identified points in time. The x-axis represents time (in seconds) and the sensor signal in time is pictured

5   as a grey scale representation. The signals represent a motion status of the user (Running, WalkingFast, Walking), noise level (Loud, Modest, Silent), luminous intensity (Dark, Normal, Bright), location, general dynamic status or orientation (AtHand, Unstable, Stable, SidewaysLeft, SidewaysRight, AntennaUp, AntennaDown, DisplayUp,

10   DisplayDown). In the grey scale signal representation, a darker grey color indicates a stronger signal and the lighter shades represent weaker signals. The signals are segmented according to the present invention, in any manner described above.

15   The vertical lines in FIG. 2 represent the borders B1-B4 which divide the time sequence into the three segments A, B, and C. The pictures P1-P4 show what is happening with the user at the segment borders of segments A, B and C: user going downstairs (P1), user exitting the stairway (P2), user exitting the building (P3) and user going inside the

20   building (P4). Pictures P1 and P5-P8 show the usage situation during the different segments: before segment A the user is walking in the corridor (P5), user in the stairway (segment A, picture P1), user walking in the corridor (segment B, picture P6) and user walking outside (segment C, picture P7). After segment C the user is walking inside

25   (P8). During segment C the user makes an operation X on the device.

In the present example, the sensor signal and corresponding user operations are represented as a sequence of segments: N1,N2,..,A,B,C(X),M1,M2,..., where N1,N2,... represents segments that

30   happened before segment A, and M1,M2,... are segments taking place after segment C. If a situation corresponding to the sequence of segments A, B and C and a user making an operation X on the device in segment C occurs often, a rule "after a sequence of segments A,B,C, initiate operation X" can be stored in the memory 7 of the device.

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FIG. 3 shows segmented sensor data collected during a later usage phase of the device. The pictures P'1-P'4 show what is happening at the segment borders B'1-B'4 of segments A', B' and C'. Pictures P'1

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and P'5-P'8 show the usage situation during the different segments. A sequence of segments A', B' and C' being the same as the previously found A, B and C are found and the previous rule can be used to initiate or predict an operation X.

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Considerable advantages are achieved with the present invention when compared with prior solutions. The methods described in the present invention enable a mobile communication device to process sufficiently large amounts of sensor data, even in mobile devices with lesser

10   processing power and limited memory resources, so that enough information of the context or external conditions of said device to make the device 10 context-aware to a feasible degree, thus simplifying its use   while enabling new services to be offered to the user than in known mobile devices. The present invention is not solely restricted to

15   the above presented   embodiments and examples, but it can be modified within the spirit and scope of the appended claims.

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